Profile LFR-43

HELENA

ITALY

GENERAL INFORMATION

NAME OF THE FACILITY	Heavy Liquid metal Experimental loop for advanced Nuclear Applications
ACRONYM	HELENA
COOLANT(S) OF THE FACILITY	Molten lead
LOCATION (address):	Italian National Agency for New Technologies, Energy and Sustainable Economic Development, C.R. ENEA Brasimone, Italy
OPERATOR	ENEA
CONTACT PERSON (name, address, institute, function, telephone, email):	Ing. Ivan Di Piazza, ENEA UTIS-TCI C.R. Brasimone 40032 Camugnano (Bo) Tel. +39 0534 801 248, Researcher of Thermal Fluid Dynamic and Facility Operation Laboratory ivan.dipiazza@enea.it

STATUS OF THE FACILITY	In operation
Start of operation (date):	2014

MAIN RESEARCH FIELD(S)

	Zero power facility for V&V and licensing purposes
	Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
X	Thermal-hydraulics
X	Coolant chemistry
X	Materials
X	Systems and components
X	Instrumentation & ISI&R

TECHNICAL DESCRIPTION

Description of the facility

The HLM loop HELENA has been designed as a multipurpose facility to support the technological development of the LFR. The first relevant feature of the facility is that it is operated in pure lead.

The reference for the piping and instrumentation is the P&ID reported in Figure 1 for the primary side, where all the instrumentation, components and pipes are listed and logically represented. Figure 2 shows an overall picture of the facility. The secondary side, filled with pressurized water at 100 *bar*, has been already designed and it will be built in 2015.

The whole facility includes:

1. the Primary side, filled with pure Lead, with 2 ½″ S40 pipes, where some main components are placed:

- ✓ a prototypical pump, operating in the range 10-40 *kg/s*, with BEP mass flow rate 30-40 *kg/s* and BEP pressure head 3.5-5 *bar*;
- ✓ a Shell and tube Heat Exchanger (HX), with 7 tubes in tubes with stainless steel power in the gap, operating in the range 10-250 *kW*;
- ✓ a high mass flow rate Venturi flow meter (3-50 *kg/s*) FM-102;
- ✓ a valve test section (T700, T800, V701, V702, V801, V802) to test prototypical ball valves in pure lead;
- ✓ a corrosion-erosion test section T107;
- ✓ a Fuel Pin Simulator (19-pins) 250 *kW* power: to be installed later, at the moment it installed on the NACIE loop for natural circulation test under mixed convection;

2. the Secondary side (to be built in 2015), filled with water at 100 *bar*, connected to the HX, shell side. It includes a pump PC-501, an air-cooler E501, by-pass and isolation valves, a heater H501, and a pressurizer S601 with cover gas;
3. an ancillary gas system, to ensure a proper cover gas in the expansion tank and to supply the bubble tubes;
4. A Lead draining section, with ½″ pipes, isolation valves and a storage tank (S200);

The facility is designed to carry out research activities in the following areas:

- ✓ Heat transfer;
- ✓ Heavy liquid metal thermal-hydraulics;
- ✓ Prototypical components operational and erosion/corrosion tests;
- ✓ Structural materials erosion/corrosion test;
- ✓ Chemistry control;
- ✓ Qualification of prototypical instrumentation;
- ✓ Computational Fluid Dynamic code validation and qualification;
- ✓ System code validation and qualification;

In accordance to these research lines, the HELENA loop has been designed with different test sections:

1. Test section for the qualification of the centrifugal pump itself and of the pump impeller for erosion/corrosion;
2. Test section of the qualification of LFR structural materials for erosion/corrosion (*fuel cladding, grids, heat exchanger tube cladding*, etc.) (planned to be installed in 2015-2016);
3. Test section for the qualification of the isolation valves operating in lead;
4. Test section for the qualification of the heat exchanger;
5. Test section for the qualification of prototypical instrumentation: flow meter, pressure transducers, oxygen probes;
6. Heating Section to study the convective heat transfer in a wire wrapped bundle;

The test section for the qualification of the centrifugal pump and of the pump impeller for erosion/corrosion implies the design and realization of a centrifugal pump with a stainless steel impeller covered with tantalum (30 micron, with the CVD technique). The pump body and all the parts of the component working in contact with flowing lead have been manufactured in austenitic stainless steel. Due to the high working temperature up to 500 °C, a packing gasket has been selected to ensure sealing. With this method a controlled leakage flow rate is collected through the draining pipes in the storage tank S200 and it is periodically

re-pumped within the primary loop, conditioned by a low level sensor signal in the expansion tank S100. The draining pipes are traced by electrical cables to avoid freezing during the continuous process. The controlled leakage will oil the gasket itself in inertial atmosphere. An upgrade is foreseen to re-pump continuously the leakage into the primary loop.
The pump includes the carter, an horizontal base and it is equipped with a 110 kW power electric motor supplied with 380 V, 50 Hz.
The pump has been installed in the HELENA facility connected to the remaining part of the loop and to the draining section and a picture of the component are shown in Figure 3.
The test section for the qualification of LFR structural material is evidenced in the P&ID as T107 and named "Corrosion Test Section". The aim of the test section is to study the erosion/corrosion phenomena in flowing lead with temperatures up to 550°C and velocities up to 2 m/s.
At the moment, the section is replaced by a 2.5'' S40 horizontal pipe. In the future, it will be designed in details and it will be made by three separated sections at different velocities, i.e. 1 m/s, 1.5 m/s, 2 m/s. The detailed geometry of the section was already designed, it will allow to locate a large number of specimens, and it will be installed in 2015-2016.
Finally an active oxygen control system is implemented. It consist of oxygen sensors (#2) installed in the loop and storage vessel (#1), gas bubbling system (in storage vessel and expansion vessel) and oxygen getter sections (in the loop and storage vessel respectively). No lead-oxide mass exchanger is foreseen.

Acceptance of radioactive material
No

3D Scheme/pictures

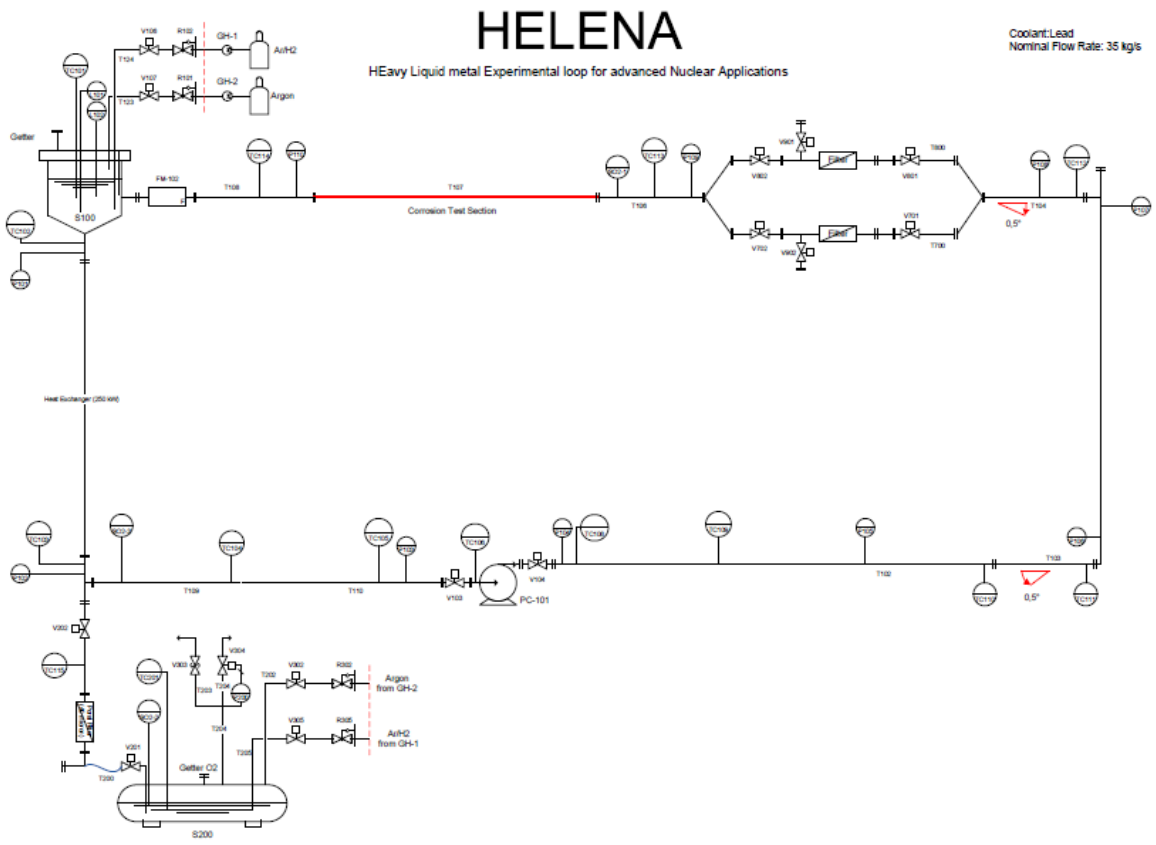

FIG. 1. P&ID of the HLM facility HELENA.

FIG. 2. Picture of the Helena facility in its final layout.

FIG. 3. Picture of the mechanical pump installed in the HELENA facility.

Parameters table

Coolant inventory	Max LEAD inventory 2200 kg
Power	Up to 250 kW
Test sections	
PUMP TEST SECTION	*Characteristic dimensions* 100 kW centrifugal pump, open coated impeller
	Static/dynamic experiment Dynamic
	Temperature range in the test section 400-480°C
	Operating pressure and design pressure Operating Pressure 8 bar (gauge) Design pressure 10 bar (gauge) Expected pressure head 4 bar
	Flow range (mass, velocity, etc.) 0-70 kg/s
Coolant chemistry measurement and control (active or not, measured parameters)	The oxygen content is continuously measured by oxygen sensor based on YSZ electrolyte cell. The oxygen content is controlled by the use of getter section in the expansion vessel and storage tank, and gas bubbling in the expansion vessel and storage tank as well.
Instrumentation	Thermocouples, pressure transducer, Gas injection system, Venturi boccaglio flow meter.

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

The HELENA loop was filled with lead in September 2014. A first test of the pump in lead was already done.

PLANNED EXPERIMENTS (including time schedule)

The scheduling of the experimental activity on the HELENA loop is to start the continuous test on the pump in 2015-2016. The test will be isothermal at 400°C-480°C with low oxygen content $<10^{-8}$ % in weight; the oxygen content will be monitored and controlled continuously. The pump will be gradually driven to the reference mass flow rate 35 *kg/s* and this mass flow rate will be maintained for 1500 *h*, i.e. 2 months about. After this, the pump is stopped and the loop is drained. Then, the pump impeller is disassembled by the body and it is inspected. After this test, in 2015-2016, a small upgrade is scheduled with the insertion of on-line filters in some sections of the facility and corrosion test section. Then, a valve test described will be carried out for a few months.

TRAINING ACTIVITIES

Training activities can be agreed with ENEA Brasimone RC for the operation of the experimental campaign under the supervision of ENEA qualified staff.

REFERENCES (*specification of availability and language*)

1. PIAZZA I. DI, TARANTINO M., AGOSTINI P., GAGGINI P., Helena: An Heavy Liquid Metal Multi-Purpose Loop For Thermal-Hydraulics, Corrosion And Component Test, ICONE22-30784, Praha, CZK, 2014.